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SIMULATION OF SYNTHETIC APERTURE RADAR III: EVALUATION OF PROTOTYPE DIGITAL FEATURE ANALYSIS DATA

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13. ABSTRACT *(Maximum 200 words)*
This experiment evaluated the suitability of the Defense Mapping Agency (DMA) prototype Level 3c Digital Feature Analysis Data (DFAD) for the simulation of Synthetic Aperture Radar (SAR). The suitability of Prototype Level 3c DFAD was evaluated by comparing simulations generated from samples of Level 3c and from samples of DFAD previously demonstrated to be adequate for SAR simulation; these products, however, were unsuitable for production in the quantities required to meet Air Force needs. B-1B Offensive Systems Officers performed a navigation update task using simulated and actual SAR images. Crosshair placement accuracy, operator confidence in the placement, and ratings of acceptability for use in a Weapon System Trainer were recorded using both simulated and actual SAR images. The results indicated that SAR simulation can be supported as well by Level 3c DFAD as by the other products.

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SUMMARY

Effectively simulating Synthetic Aperture Radar (SAR) requires more detailed Digital Feature Analysis Data (DFAD) than currently provided by Defense Mapping Agency (DMA) standard Digital Landmass System products. Although several DFAD prototypes have been demonstrated to support SAR simulation, these prototypes cannot be produced in sufficient quantities to meet simulation requirements. DMA has proposed an interim high-resolution DFAD called Level 3c, which can be produced in quantity using standard DMA production methods. The preliminary specifications for Level 3c appear to meet the criteria for data base density recommended by previous research. At the request of the Aeronautical Systems Division, Deputy for Training Systems, simulations created from Level 3c DFAD were compared to simulations created from two other prototype DFADs that earlier research indicated were sufficient for simulating current B-1B SAR. B-1B Offensive Systems Officers (OSOs) performed a navigation update task using both simulated and actual SAR images that had been prerecorded. The dependent variables were accuracy of crosshair placement, operator confidence in placements, and ratings of acceptability for use in Weapon System Trainers. The results demonstrated that SAR simulations generated from Level 3c supported OSO task performance equally as well as did the other high-resolution DFAD products. We therefore recommend that the Air Force accept Level 3c as an interim high-resolution DFAD product for simulating current SAR systems such as those on the B-1B and F-15E.

PREFACE

The present effort was conducted in support of the Air Force Human Resources Laboratory's Technical Planning Objective: Aircrew Training Technology. The goal of this program is to develop cost-effective strategies and equipment for aircrew training. The research was supported under Work Unit 1123-33-01, Fidelity Requirements for Sensor Imagery.

We thank the personnel of the 96 BMW, 319 BMW, AAMRL/HE, ASD/ENETV, ASD/YWB, HQ DMA, and DMAAC for their help in this project. We also thank Major Michael Seiverding, who was project manager for this evaluation.

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I. INTRODUCTION

Simulating Synthetic Aperture Radar (SAR) imagery requires Digital Feature Analysis Data (DFAD) with greater feature density than is currently contained in standard simulator products from the Defense Mapping Agency (DMA). To help determine DFAD requirements for simulating SAR, DMA developed a prototype high-resolution DFAD specification, Level X, which incorporated all ground features 10m or larger on a side. The feature density in Level X was much greater than for standard products such as Level 1, which has a 100m capture criterion, or Level 2, which has a 30m capture criterion.

An engineering analysis (TASC, 1985) concluded that Level X would support SAR simulation for Weapon System Trainers (WSTs). Production of Level X in quantity, however, is impractical due to the coverage required by the major commands who use the products and due to the large number of man-hours required to produced Level X DFAD.

Because of DMA's inability to produce Level X DFAD in sufficient quantities, Headquarters Air Force tasked the Aeronautical Systems Division's Deputy for Training Systems (ASD/YW) to define an alternative DFAD product that would meet the SAR simulation needs of the current B-1B and F-15E WSTs. ASD/YW requested the Air Force Human Resources Laboratory's Operations Training Division (AFHRL/OT) and the Aeronautical Systems Division's Support Engineering Division (ASD/EN) to assist them in defining DFAD requirements for simulation.

Three previous experiments were conducted by AFHRL/OT and ASD/EN to define minimum DFAD requirements for SAR simulation (see Crane, Bell, Kalinyak, Dooley, & Hubbard, 1989, for a detailed description of these experiments). In Experiment 1, SAR simulations were generated using the high-resolution prototype DFAD, Level X, with a 10m capture criterion, and a current DMA product, Level 2 DFAD, with a 30m capture criterion. In addition, simulations were also developed using two experimental DFADs with 15m (Level Y) and 20m (Level Z) capture criteria. These simulations were judged for acceptability by SAR-experienced Air Force officers, who indicated that a capture criterion of between 15 and 20m would produce SAR simulations with acceptable fidelity.

Experiment 2 defined the ground features that are critical for performing radar scope interpretation (RSI) with SAR imagery. The features most often identified as critical by SAR-experienced officers were lines of communication (e.g., roads, railroads, and canals) and large natural features (e.g., treelines, shorelines, and cultivated fields). Nearly all of these critical features are included in DMA Level 2 DFAD. Small individual features such as structures, which are included in Level X as well as the Level Y and Level Z experimental DFADs, were rarely cited as task critical.

The results of these experiments appear to contradict each other. The major conclusion drawn from Experiment 1 was that a data base density greater than current DMA Level 2 DFAD was required to support SAR simulation. The results of Experiment 2, however, indicated that RSI is based primarily on the large features and lines of communication contained in Level 2 DFAD, rather than the small individual features unique to Levels X, Y, and Z. Based upon the comments of the subject-matter experts in Experiments 1 and 2, it appears that the small individual features contained in Levels X, Y, and Z function primarily to provide the ground

detail needed to approximate the familiar level of image clutter within the simulated SAR image. If this is indeed the case, then these smaller features might be depicted generically without affecting task performance.

This hypothesis was tested in a third experiment using a navigation update task in the B-1B Engineering Research Simulator (ERS) at Dyess AFB, Texas. SAR simulations were generated using Level X (10m), Level Y (15m), Level 2 (30m), and Level 1 (100m) DFAD. The Level 2 and Level 1 DFAD were enhanced by subdividing high-density areas into smaller generic features (see Crane et al., 1989, for an explanation of the enhancement procedures). B-1B Offensive Systems Officers (OSOs) performed a navigation update task using these simulations and actual SAR imagery. The results showed no significant differences in either the accuracy of crosshair placement or the OSOs' confidence in their placement between the actual SAR imagery and simulations generated from Level 2 enhanced, Level Y, and Level X.

These three experiments indicated that: (a) lines of communication and large natural features are the principal features used in the interpretation of SAR imagery, (b) small features are required to provide the correct SAR-like appearance in high-density areas, and (c) these small features need not be represented with ground truth accuracy. Based on these results, an enhanced Level 2 DFAD was recommended as being acceptable for simulation of current SAR systems.

Unfortunately, DMA is unable to produce an enhanced Level 2 as a standard product. DMA proposed, however, that a high-resolution DFAD could be produced by digitizing cartographic products such as 1:250,000 Joint Operations Graphics and 1:50,000 topological maps. Called Level 3c, this DFAD product would have a feature density similar to that of the enhanced Level 2 but would use fewer separate feature codes to define the unique characteristics of the individual DFAD features.

The objective of this experiment was to evaluate the effectiveness of Level 3c DFAD for simulating SAR. The procedure used in this evaluation was similar to the previous performance evaluation using B-1B OSOs. The results indicate that Level 3c is adequate for simulating current B-1B-type SAR imagery.

II. METHOD

Subjects

The subjects were B-1B OSOs: 24 from the 28th BMW, Ellsworth AFB, South Dakota; 10 from the 319th BMW, Grand Forks AFB, North Dakota. The average flight experience for these OSOs was 239 hours in the B-1B and 2,087 hours overall.

Task

The experimental task was similar to that used in our previous performance experiment. Each SAR-experienced OSO first studied Fixpoint Graphics of nine separate aimpoints in the Strategic Training Range Complex and then performed a simulated radar navigation update over each aimpoint, using either simulated or actual SAR imagery of the aimpoint and its surrounding area. After each radar update, the OSO rated his confidence in the accuracy of his crosshair placement. Following the completion of all nine navigation updates, the OSOs rated photographs

of each image they had seen, for its acceptability as a SAR simulation to support WST training tasks.

The navigation update task was simulated on the B-1B Engineering Research Simulators (ERSs) at the 28th BMW and the 319th BMW. Only the radar screen and track handle of the OSO station in the ERSs were used in this experiment. The SAR images of the aimpoints were generated off-line, stored on video disk, and presented in the appropriate order to each subject. Since the ERS uses video disk to store images, actual as well as simulated SAR images could be presented in the simulator.

Aimpoints

A subject-matter expert from Strategic Air Command (SAC/XPH) selected the nine aimpoints from among the 15 aimpoints used in the previous task performance experiment. The coordinates of each aimpoint are given in Appendix A.

Data Base and Image Generation

For each of the nine aimpoints, Level 2 enhanced (2e), Level 3c, and Level X DFAD were obtained from either DMA or from ASD/ENETV. SAR data bases were then created for each combination of aimpoint and DFAD level. Twenty-seven SAR data bases (nine aimpoints x three levels of DFAD) were built for AFHRL's Advanced Visual Technology System (AVTS). Simulated SAR images were then generated from each data base for each of the nine aimpoints, using the SAR simulation capability of AVTS. The characteristics of the AVTS SAR simulation process are described by Ferguson, Ellis, French, Ball, Spencer, Bell, and Crane (1989). Each simulated fixpoint was a .625- x .625-nautical mile (nm) patch, with the aimpoint near the center of the patch. For each simulation, the radar illumination angle was set to match the radar illumination angle of the actual SAR image recorded for each fixpoint. All imagery was generated North-up.

Each aimpoint was simulated from two depression angles, with range and altitude appropriately adjusted. In order to match the recorded SAR imagery for the high depression angle simulation, the simulated range was 7-9nm, with an altitude of 8,000-10,000 feet above ground level (AGL). For the low depression angle condition, the range was 8nm and altitude was 850 feet AGL.

Research Design

The factorial combination of the nine aimpoints, three DFAD levels, and two depression angles resulted in 54 simulated SAR images. In addition, actual high depression angle SAR images were available for each of the nine aimpoints. These simulated and actual SAR images were combined to create the 63 SAR images used in this experiment:

Nine Aimpoints x {(three DFAD Levels x two Depression Angles) + one High Depression Angle Actual SAR} Images Per Fixpoint.

The experimental design was an incomplete block factorial. Each OSO saw each of the nine aimpoints once during the experiment. Seven of the nine aimpoints represented the seven unique combinations of image source (DFAD Level 2, 3c, X, or actual SAR) and depression angle (high or low, with only high depression angle for the actual SAR). The two remaining

aimpoints represented the replicates of various image source by depression angle combinations. The presentation of various fixpoint by image source by depression angle combinations was balanced across subjects and the presentation order of the aimpoints was randomized for each OSO.

Procedure

Briefing. Each OSO was briefed individually. The purpose of the experiment and the type of data to be collected were described. The OSO was then given 10 minutes to study the Fixpoint Graphic cards of the nine aimpoints plus Fixpoint Graphic cards for two additional aimpoints used as warmup trials.

Warmup Trials. All OSOs received two warmup trials using the same images; performance and confidence data were recorded but not retained for analysis. After both warmup trials, there was a pause for the experimenter to answer any questions.

Data Collection. The OSO's task was to locate the aimpoint on the radar screen within 60 seconds. Before each trial, the OSO was given 30 seconds to review the Fixpoint Graphic. At the end of the review interval, the screen alphanumerics were illuminated and a tone sounded, indicating that the OSO should request a radar map. When the map was completely drawn, the crosshairs appeared in the center of the screen and a response clock started. The OSO moved the crosshairs to the aimpoint by depressing the track handle trigger and pushing a thumb control. When satisfied with the crosshair placement, the OSO depressed a button on the track handle to blank the screen and end the trial. The coordinates of the crosshairs at the time the OSO depressed the button (indicating that he had located the aimpoint) were recorded. If an aimpoint was not selected within 45 seconds, a warning tone sounded. If the aimpoint was not selected within 60 seconds, the screen blanked automatically, erasing the image; and the trial was terminated. After the target was designated, the OSO rated his confidence in the accuracy of his crosshair placement, on a 7-point scale ranging from "1--Complete Guess" to "7--Very High Confidence." The experimenter entered this rating at a terminal and started the study period for the next trial. After performance data were collected for all nine trials, each OSO was shown photographs of the images he had seen in the simulator, along with the appropriate Fixpoint Graphic. The OSO examined each image and, by selecting a number from "0--Not Adequate" through "4--Fully Adequate," rated the image as to its adequacy for WST training tasks.

III. RESULTS AND DISCUSSION

Placement Accuracy

Crosshair placement accuracy was defined as the radial miss distance between the subject's placement of the crosshairs and the ideal placement for each image as defined by the Strategic Air Command subject-matter expert. To make variances more uniform across conditions and to reduce the relative importance of a few very poor crosshair placements, a logarithmic transformation was applied to the miss distances. This transformation can be expressed as:

$$X' = \mathrm{Log}_2\,(X + 1)$$

$$Y' = \mathrm{Log}_2\,(Y + 1)$$

$$d = (X'^2 + Y'^2)^{1/2}$$

where X is the untransformed miss distance on the horizontal axis, Y is the untransformed miss distance on the vertical axis, X' and Y' are the transformed miss distances on each axis, and d is the radial miss distance used in the analysis. Figure 1 shows the mean of these transformed distances as a function of image source and depression angle, in arbitrary units forming a ratio scale.

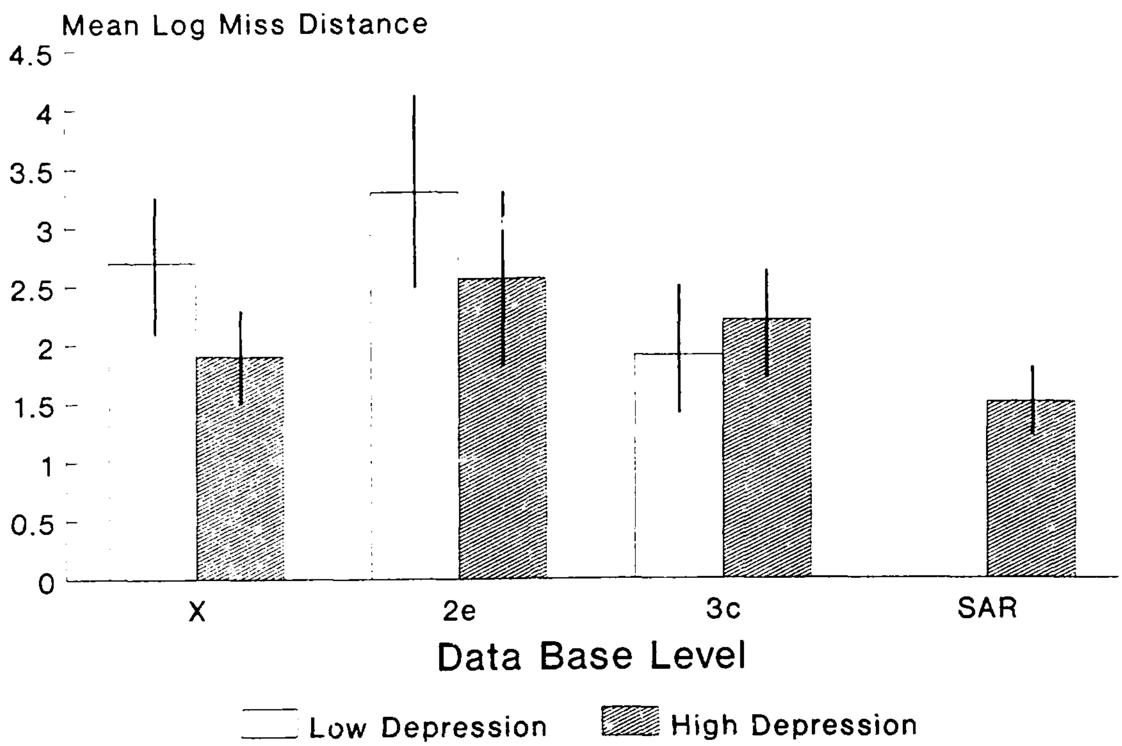

Figure 1. **Mean Log Miss Distances for Levels X, 3c, 2e, and SAR for High and Low Depression Angles. Miss distances are in arbitrary units forming a ratio scale. Error bars are 95% confidence limits.**

The miss distances were statistically analyzed using an incomplete blocks model analysis of variance. No significant effects were found for depression angle or the depression angle by DFAD interaction ($p > .05$). Comparisons of simulated and recorded SAR, however, must be limited to the high depression angle condition since low depression angle SAR imagery was not available. Overall, placement accuracies for Levels X and 3c were not significantly different from each other and were significantly more accurate than placements for Level 2e [$F(2, 192) = 4.52$, $p = .012$]. At high depression angles, accuracies for SAR, Level X, and Level 3c were not significantly different from each other and neither were placement accuracies for Levels X, 3c, and 2e significantly different from each other; placement for SAR was more accurate than for Level 2e [$F(1, 192) = 4.18$, $p = .042$].

Confidence

OSO confidence in placement accuracy was rated on a scale of 1 to 7. The ratings were analyzed using an incomplete blocks model analysis of variance. Mean confidence ratings are shown in Figure 2. OSOs were more confident in their placements with high depression angles than with low depression angles [$F(1, 192) = 10.20$, $p < .01$]. The depression angle by DFAD interaction was not significant, ($F < 1$). At high depression angles, confidence for Level X was higher than for SAR [$F(1, 192) = 10.81$, $p < .001$] while there were no significant differences

between the various DFAD levels. Overall, confidence for Level X was higher than for Levels 3c and 2e [$F(2, 192) = 7.32$, $p < .001$].

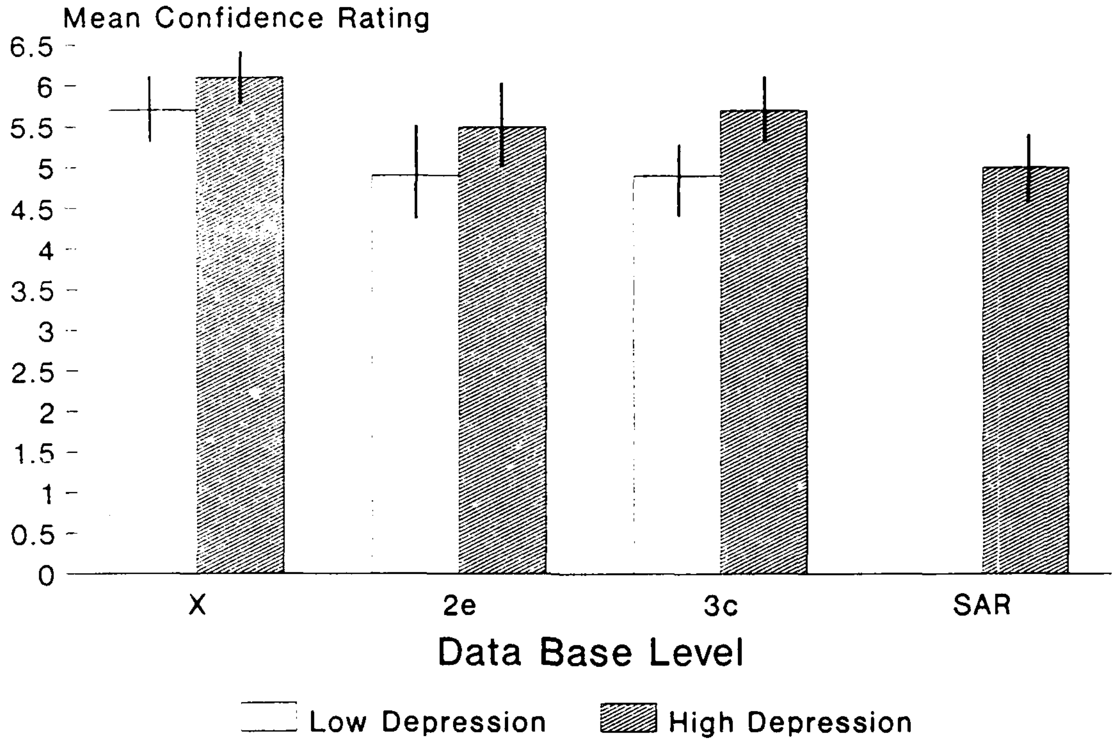

Figure 2. **Mean Confidence Ratings for Levels X, 3c, 2e, and SAR for High and Low Depression Angles. *Error bars are 95% confidence limits.***

Acceptability Ratings

OSOs rated each image for acceptability in WST training on a scale from 0 to 4. The ratings were analyzed using an incomplete blocks analysis of variance. Mean ratings are shown in Figure 3. High depression angle images were rated as more acceptable than were low depression angle images [$F(1, 198) = 18.11$, $p <$ 01]. The altitude by data base level interaction was not significant ($p > .10$). At high depression angles, SAR images were rated as significantly less acceptable than Level X [$F(1, 198) = 4.29$, $p = .039$], whereas ratings for 3c, 2e, and SAR and for X, 3c, and 2e were not significantly different from each other. At low depression angles, ratings for Levels X, 3c, and 2e were not significantly different from each other. Overall, ratings for Level X were higher than for Level 3c or Level 2e [$F(2.\ 198) = 9.67$, $p < .01$]; ratings for Levels 3c and 2e were not significantly different from each other.

OSO Comments

Several of the OSOs wrote comments on the rating forms regarding specific images. Because these comments were not collected systematically, they cannot be coded for statistical analysis. However, review of the comments shows that most of them concerned vertical incidence effects and the simulation of shadows and were not affected by data base level. Comments specific to Level 3c were criticisms of how storage tanks were depicted (i.e., they were often too small in comparison to the Fixpoint Graphic image). The AVTS data base modelers at AFHRL noted that only one size tank Feature Identification Descriptor was available in the Level 3c specification;

thus, the same size was applied to all storage tanks in the evaluation. Tanks of varying sizes were used in the Level X and Level 2e images.

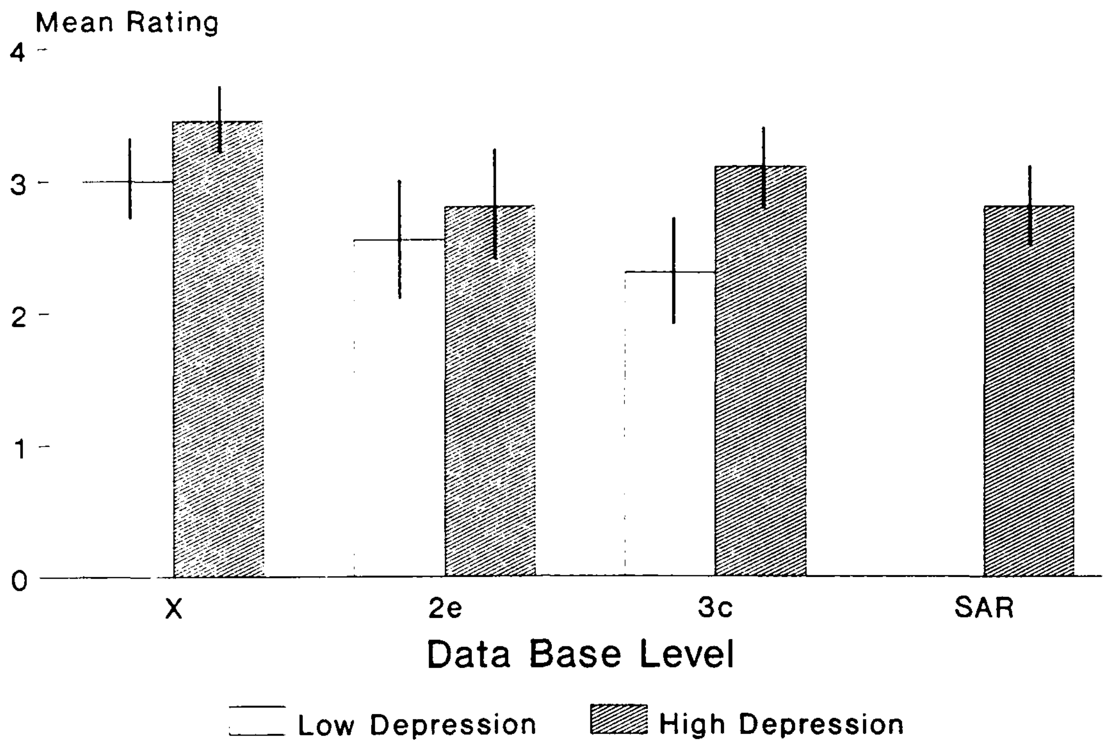

Figure 3. **Mean Acceptability Ratings for Levels X, 3c, 2e, and SAR at High and Low Depression Angles. Error bars are 95% confidence limits.**

IV. DISCUSSION

Data Base Density

Our previous research on data base requirements for simulating SAR (Crane et al., 1989) showed that the high-density ground truth information characteristic of Level X (10m) or Level Y (15m) is not required. That is, the density of Level 2e is sufficient to support SAR task performance. Counts of the point, line, and areal[1] features for the Level X, 2e, and 3c data bases used in the present experiment show that the density of Level 3c is equivalent to that of Level 2e, and both Levels 3c and 3e have fewer features than does Level X. These feature counts are shown in Figure 4. Of the nine scenes used in this experiment, four contained high-density areal features, and patterns of small features were added to these high-density areas in Level 2. The remaining five scenes did not contain high-density areas, and the Level 2 data bases were not enhanced. For the scenes which required enhancement, the Level 3c DFAD had only 75% of the features found in Level 2e, with the major difference relative to line and areal features. However, for the scenes which did not require enhancement, 3c had an average of 55% more features per scene than did Level 2, including more than seven times

[1] An areal feature is distinguished from a point or line feature in that it is depicted as a two-dimensional surface delimited by a surrounding border.

the number of point features. Overall, the density of 3c equals that of 2e but compared to unenhanced Level 2, the increase in density is more uniform across scenes and is therefore less likely to show areas of high density surrounded by low feature density.

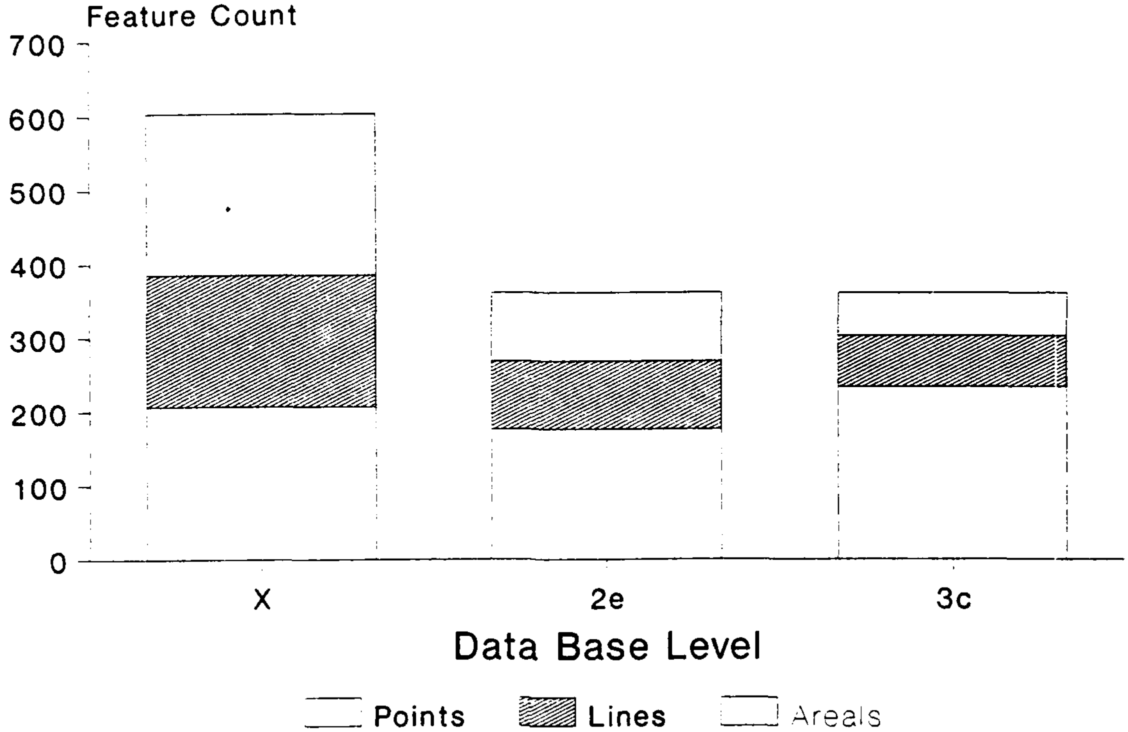

Figure 4. **Mean Feature Counts for Point, Line, and Areal Features in the Nine Scenes Used in the Level 3c Evaluation Experiment.**

Performance Data

Placement Accuracy. The results of our previous OSO task performance experiment (Crane et al., 1989, experiment 3) cannot be directly compared to the results of the present experiment because of differences between the image sets used in the two studies. In the previous experiment, there were 15 scenes divided into three groups: urban, small group, and isolated. In the present experiment, there were only nine scenes in a single group. To make direct comparisons, the data from the previous experiment have been reanalyzed by selecting only those aimpoints included in both experiments. In Figure 5, the mean log miss distances from the earlier experiment are compared to the high depression angle results from the present experiment. In the earlier experiment, SAR operator placement accuracies for Level 2e, Level X, and recorded SAR images were not significantly different from each other. In the present experiment, crosshair placements at high depression angles were significantly more accurate for SAR than for Level 2e. Examination of Figure 5 shows that this change resulted not from a decrease in performance for Level 2e but from a significant improvement in placement accuracy for actual SAR images. The crosshair placements for SAR obtained in the present experiment were not only more accurate than for Level 2e in this experiment but also more accurate than the placements for Level 2e, Level X, and actual SAR from the earlier experiment. Placement accuracies for Levels 2e and X did not change significantly from the first experiment to the second.

Confidence. A similar analysis of confidence ratings shows that the ratings for Levels 2e and X did not change significantly between the two studies (see Figure 6); however, confidence ratings for SAR decreased.

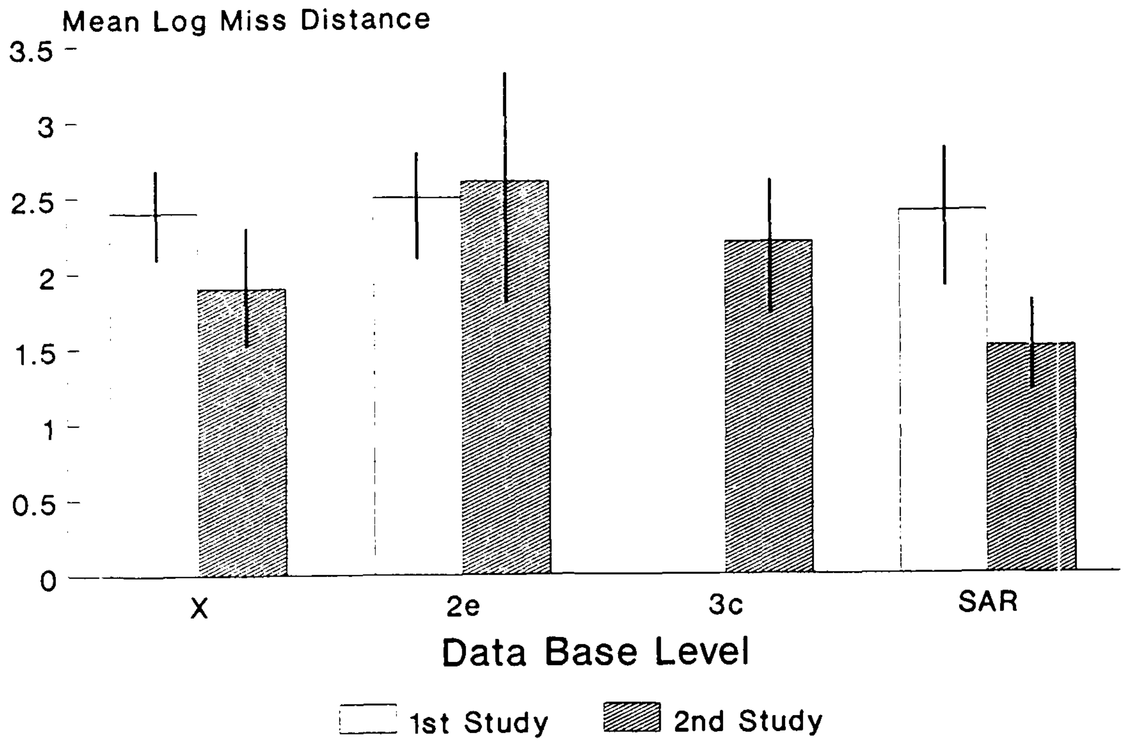

Figure 5. **Comparison of Placement Accuracy Results from a Previous OSO Task Performance Experiment to the Level 3c Evaluation Experiment. Error bars are 95% confidence limits.**

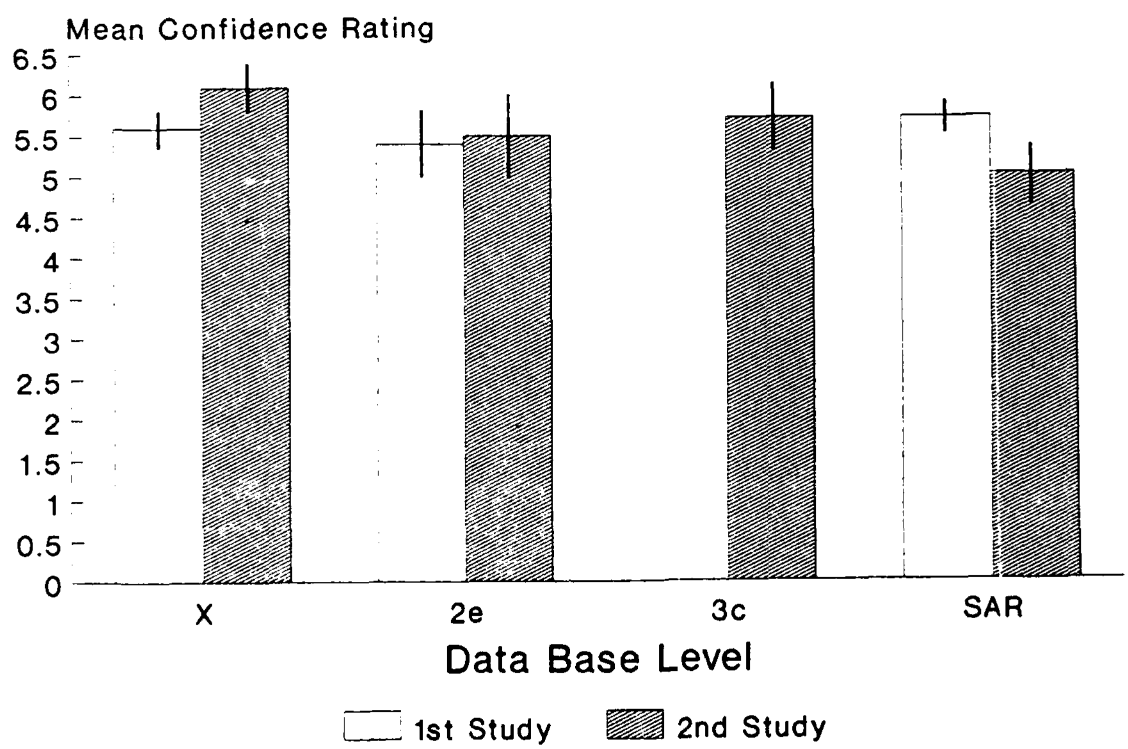

Figure 6. **Comparison of Confidence Ratings from a Previous OSO Task Performance Experiment to the Level 3c Evaluation Experiment.**

Summary

Results of this experiment closely parallel those obtained by Crane et al. (1989), except for the SAR data. For SAR, in the present experiment, placement accuracy increased while confidence ratings decreased. It should also be noted that acceptability ratings for SAR in this experiment were lower than for any of the simulations, although the difference was significant only when compared to Level X. No explanation is offered for these findings. Placement accuracy and confidence for Level 3c are not significantly different from the results obtained for Level 2e, Level X, and SAR from either experiment.

V. CONCLUSIONS

Data Base Density

The research on data base requirements reported by Crane et al. (1989) concluded that DFAD with sufficient density to support SAR simulation would capture as many features as Level 2e. The density of features in Level 3c is less than that in Level X, greater than that in Level 2, and similar to Level 2e. Level 3c also has a more uniform distribution of features than does Level 2e. This increase in feature density was achieved, in part, by compressing the number of Feature Identification Descriptors in the 3c specification and thus reducing the range of discriminations that might be made regarding feature type, height, and reflectivity.

OSO Task Performance

The data collected on placement accuracy, confidence, and ratings of acceptability show that Level 3c DFAD can support SAR simulation for the B-1B WST. Compression of feature identifiers did not adversely affect operator task performance, except for the problems noted regarding the identification of storage tanks.

VI. RECOMMENDATIONS

We recommend accepting the proposed Level 3c as a high-resolution DFAD product to support simulation of current Air Force SAR systems such as the B-1B and F-15E. We further recommend that DMA continue to consult with Air Force subject-matter experts to eliminate specific problems with the specification as these problems are identified.

REFERENCES

Crane, P.M., Bell, H.H., Kalinyak, R.G., Dooley, J., & Hubbard, D.C. (1989). *Simulation of synthetic aperture radar I: Feature density and accuracy requirements (AFHRL-TR-88-42, AD-A211 019). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.*

Ferguson, R.L., Ellis, J., French, S.R., Ball, J., Spencer, L., Bell, H.H., & Crane, P.M. (1989). *Simulation of synthetic aperture radar II: Simulating SAR using the Advanced Visual Technology System* (AFHRL-TR-89-16, AD-A213 659). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

TASC. (1985). *Near real time SAR simulation, phase II, final report.* Reading, MA: The Analytical Sciences Corporation.

APPENDIX A: AIMPOINT COORDINATES

Level X radar fixpoint number	WGS coordinates	
3	44-52.44N	104-09.72W
4	44-16.54N	104-57.95W
5	45-23.08N	106-17.23W
6	44-29.32N	108-03.32W
7	44-49.06N	108-30.34W
19	46-20.88N	102-37.22W
20	47-18.33N	102-11.98W
26	45-44.18N	107-34.47W
36	45-23.50N	101-25.84W

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